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Technical Note N-1222

IN-PLACE MAINTENANCE PAINTING OF STEEL PILING

By

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ABSTRACT

Several materials and application procedures have been investigated for use in the in-place maintenance painting of steel piling. Coatings designed for application to dry sandblasted piling above the waterline have performed well for two years. Coatings designed for application between tides, so that they are wetted with seawater almost immediately after application, or for application underwater, have performed well for one year.

Application above water was accomplished by conventional spraying. Part of the application between tides and a few feet below mean low water was accomplished by a special cofferdam designed for use on steel sheet piling. The rest was accomplished by brushing coatings specially formulated for underwater application. Surface preparation for the latter application was generally by underwater sandblasting, but cleaning with a pneumatic needle gun was also investigated. Laboratory testing indicated that needle gun cleaning was a promising technique. It was also used to screen candidate underwater-applied coatings.

While the performances of some test coatings are quite promising to date, their further exposure and investigation of new materials and application procedures will continue in order to make them more practical and economical.

INTRODUCTION

The capability of applying protective coatings to structures between tides and underwater has long been desired, but until comparatively recently relatively little research in this area had been undertaken. In the past few years, however, the new emphasis placed upon exploitation of the oceans and a renewed look at methods of reducing maintenance and replacement costs for marine structures have led to investigations of new materials and procedures for providing this capability.

Coating tests have demonstrated that certain protective coatings, when properly applied to steel piling before driving, will give 15-20 years of protection.[1,2,3] Other research and tests have demonstrated the feasibility of "splash-zone" compounds for maintenance coating repair on mooring buoys and steel or concrete structures.[4,5,6] Recent developments in coatings technology have produced coatings which are tolerant to damp or wet surfaces and can be brush applied.[7,8] Present research is directed toward formulation of coatings which can be applied underwater. A few coatings, mostly experimental, show some promise for underwater application.[9] Surface preparation for these coatings requires the very slow procedure of underwater sandblasting. Some success in removing rust and scale from steel underwater has been obtained at NCEL by use of a Von Arx type of needle gun.

The coating application underwater is also slow and arduous. Some success has been acquired by use of a pressure-fed brush. In-place application underwater of protective coatings, including splash-zone compounds, has been time consuming and therefore costly. There are several chemically cured, solvent-free coatings which will cure satisfactorily when placed underwater immediately after application. Thus, a procedure for the surface preparation and coating application for in-place steel piling maintenance is needed such that rapid sandblasting and painting of underwater piling can be done under conditions similar to those existing for on-shore operations in the atmosphere.

This report covers the research, investigations and tests conducted to date by the Naval Civil Engineering Laboratory in maintenance painting of in-place steel sheet piling.

AREAS OF CONSIDERATION

The areas of corrosion of steel sheet piling requiring maintenance painting can be divided into roughly three overlaping sections. The

splash and atmospheric areas extending from a few feet (depending on the tidal range) above midtidal area, upwards to the top of the piling; the Mean Low Water (MLW) area extending from the midtidal area to possibly 2 feet below MLW; and the immersed area extending into the mud line.

The immersed area has a relatively low rate of corrosion, generally, and if not painted before driving can be protected by cathodic protection,[10,11] although cathodic protection is usually most effective in conjunction with protective coatings. Cathodic protection is effective upwards to the MLW level and will give partial protection about one-third of the way between MLW and MHW (Mean High Water) depending upon the tidal range.[10,11]

The atmospheric and splash areas can be protected by routine sandblasting and application of a durable coating[2,3,9] either before or after driving.

The area of most concern during in-place maintenance painting is in the all-wet tidal area to about 2 feet below MLW. Two techniques can be used for maintenance painting in this area. One technique is to withhold the water from the face of the piling until sandblasting and painting is accomplished; the second technique utilizes underwater sandblasting (or use of a pneumatically powered gun with a bundle of chisel-shaped needles) and underwater coating application. The first method is probably more economical and practical for use over large areas and the second for small areas of maintenance painting.

LABORATORY EXPERIMENTAL PROCEDURES

Investigation of Candidate Materials

Preliminary laboratory research was conducted by NCEL to determine the ability of candidate coatings to meet field requirements.[9] The test coatings were brush applied to sandblasted 2-inch by 6-inch steel specimens under three surface conditions: Dry, wet with seawater, and under seawater. The steel specimens which were coated either dry or wet were placed in a vertical position in air for several minutes to observe any tendency to sag and then placed in a vertical position in seawater so that one-half of the coating was immersed and one-half exposed to the air. Condition of coating and extent of curing were determined periodically. Additional sandblasted steel specimens were immersed in seawater in the field and candidate coating brushed onto them. The ability of the coating to displace water and preferentially wet the steel substrate and to flow out over the steel surface was observed. Also, the brushability of a coating when applied to steel underwater and the ease of application of a topcoat underwater to a previously applied primer were observed. After the required curing time the coatings were tested for completeness of cure by hardness and bonding by resistance to peeling (Figure 1). Many coatings were readily

applied to surfaces dry or wet with seawater and subsequently cured well under seawater, but very few were capable of being applied under seawater and subsequently curing to a hard film. The best candidate materials were used in the field applications described below.*

Testing of Pneumatic Needle Gun for Surface Preparation

A laboratory test was conducted to determine the relative bonding strengths of viscous polyamide-cured epoxy compounds (splash-zone compounds) to steel surfaces cleaned underwater by a pneumatic needle gun, as compared to such materials bonded to steel surfaces cleaned by more conventional methods. Steel panels pre-rusted in seawater were cleaned by sandblasting, wirebrushing, or using a Von Arx Model 3B needle gun (Figure 2), made by Von Arx Limited of Sissoch, Switzerland, but available through local suppliers. Both 2mm and 3mm width needles were used in the gun so that comparisons of their effectiveness could be made. The former were found to be much easier and faster to use.

After the steel panels had been cleaned (Figure 3), pairs were bonded together with splash-zone compound, cured under seawater for one week, and tested as described in NCEL Technical Report R-300.[4] Andrew Brown Splash-Zone Compound and Cutty Sark Splash-Zone Compound (DM-1512 Splash-Zone Mastic and DM-1513 Epoxy Activator) were the two proprietary bonding materials used. Bonding strengths of the various specimens are listed below in Table 1.

Table 1. Breaking Strengths in Pounds Per Square Inch of Steel Specimens With Different Surface Preparations Using Splash-Zone Compounds.

Splash-Zone Compound	Cleaned with Von Arx Gun		Cleaned by Sandblasting	Cleaned by Wirebrushing
	2mm Needles	3mm Needles		
Andrew Brown1/	850	385	825	725
Andrew Brown1/	815	385	820	300
Cutty Sark2/	660	435	850	400
Cutty Sark2/	395	395	845	420

1/ Andrew Brown Company, 5431 So. District Blvd., Los Angeles, California 90022

2/ Admiral Paint Company, Inc., Lake Charles, Louisiana 70601

*A list of coatings that were tested in the laboratory is found in Appendix A.

As expected, sandblasting was found to be the best method of surface preparation in that sandblasted specimens had the greatest bonding strengths, with the least variation in strength. Specimens using Andrew Brown Splash-Zone Compound and panels cleaned with the Von Arx gun using 2mm width needles had as great a bonding strength, but specimens with similarly prepared panels and Cutty Sark Splash-Zone Compound did not. The average bonding strength of the latter specimens was equivalent to that of wire-brushed specimens using Cutty Sark Splash Zone Compound. The average bonding strength of specimens with panels cleaned using a Von Arx gun with 3mm width needles was slightly less than that of wire-brushed panels. The bonding strengths of the specimens cleaned with the Von Arx gun using 2mm width needles and the ease of using this gun were such as to indicate that the use of this method of cleaning steel piling immersed in seawater should be field tested.

FIELD APPLICATION

A section consisting of steel sheet interlocked piles in the quay wall of Pier 6 in Port Hueneme Harbor was selected as a site for application of test protective coatings, Figure 4. Test areas were to include the tidal area and down to about 2 feet below MLW. A description of each coating system is given in Appendix B. Proprietary sources of all coating materials are given in Appendix C.

Atmospheric and Splash Zone Areas

Prior to application of test coatings in the atmospheric and splash area, all piling in the test area were sandblasted to a commercial grade of surface preparation from MLW to the top of the piling. A steel platform was suspended from a crane down the front of the quay wall to provide a support for the sandblaster and the painter. Before each protective coating was applied, one previously cleaned section, consisting of three interlocked sheet steel piles (160 spare feet), was given a quick brush blast to remove the light rust formation that accumulated since the initial cleaning. The coatings were applied using conventional air spray equipment. This series of tests were described in a previous report.[9]

Mean Low Area - Cofferdam Concept

To simulate atmospheric on-shore field painting conditions, the operator must be able to sandblast and paint without the need for diving equipment and with seawater removed from the face of the piling. Reviewing several possible approaches led to an investigation of the feasibility of a cofferdam concept.[12] The steel sheet piling available in Port Hueneme Harbor for use in the applications of test coatings were interlocking Z-shaped piles comprising part of a quay wall near Wharf 6.

Design of a cofferdam required that the floor facing the piling be constructed so as to form fit against the repetitive pattern created by the interlocked piles, Figure 4. Measurements required in the design revealed that the distances between the seam between two sheet piles and a like seam four piles removed (in either direction) was 73 $\pm$ 4 inches. Thus, as one traversed the face of the piling, a form cut to fit snugly in one area could leave as much as 4 or more inches of open space in another area. To accommodate this nonuniformity of pattern on the face of the piling, a self-adjusting seal was developed. The seal was fabricated from a 1-5/8-inch ID (inside diameter) by 3/4-inch sidewall sponge rubber tube, Figure 5. Two 26-inch by 1.76-inch bycicle inner tubes were cut and spliced so as to produce one long tube. This long tube was fitted inside of the sponge rubber tube and sealed at the exposed ends. A hand operated pump was used to inflate the inner tube when desired. The vertical scales at each side of the cofferdam were made of 4-inch by 4-inch strips of polyurethane foam rubber. The cofferdam was constructed of 3/4-inch plywood. The form fitting bottom was made 3 inches wide to support the sponge rubber tube. Three-quarter-inch plywood was fastened top and bottom of the 3-inch wide bottom to create a 1/2-inch deep protective channel for the sponge rubber tube. Three-inch by three-inch angle irons were used inside and out to strengthen the cofferdam frames. The overall dimensions of the cofferdam were 72 inches high, 78 inches wide, and 40 inches deep, Figures 6 and 7. The 78-inch width permitted coating the complete width of four interlocked piles. The 40-inch space away from the piling face allowed room for a man to work comfortably. The design of supporting hardware utilized turnbuckles mounted on the sides of the cofferdam which were in turn fastened to shoulder padeyes. Holes were drilled into the sheet piling and threaded. The shoulder padeyes were screwed into these threaded holes.

The test cofferdam was used when sandblasting and applying coatings in the lower tidal all-wet area down to about 2 feet below MLW, Figure 8. Some coatings were brush applied, others were sprayed on. Two piles were coated with each test coating. In this manner four piles, representing two coating systems, were applied during one emplacement of the cofferdam. The area covered was about 60 square feet total for the two systems. The cofferdam protected about 6 linear feet (or 8.5 feet along the face of the pile) and 7 feet vertically during coating application.[12]

Immersed Area

Only one pile width was used per coating for the underwater coating application. For those coatings applied underwater, the sandblasting was accomplished by a scuba diver at high tide from about 2 feet below the MLW level up to and overlapping the coating applied in the tidal area (approximately 4 square feet). The staging (safety cage) used above water was also used to support the divers underwater. Sandblasting underwater was slightly faster when the nozzle was pointed in a slightly upward direction (approximately 60 degrees to the piling). Immediately

after sandblasting, the protective coating was applied underwater over this area. Application of underwater coating materials was primarily by conventional brushing. However, in some instances paint was supplied to the brush under pressure through a hole in the handle of the brush, Figure 9. This method of introducing paint to the brush bristles was somewhat more efficient than when dipping the brush into a paint bucket underwater because some paint was lost during transfer of paint to brush by the latter procedure.

For some coatings intended for underwater cure or application, removable simulated steel piles were used also. These simulated piles facilitated subsequent inspection and rating of the exposed coatings. Immediately after application of the test coating of these removable piles, they were suspended so as to extend into the atmospheric, tidal and immersed areas. Von Arx gun cleaned surfaces were prepared and painted one year after those cleaned by sandblasting and were limited to the simulated steel piles.

RESULTS

The coatings performance ratings are tabulated in Table 2.

Coatings Applied Above Mean Low Water (MLW)

These coatings were applied from a suspended steel platform during the period of low tide. Application was by brush or spray from near MLW upwards through the splash and atmospheric zones. Shortly after application these coatings were wetted by the rising harbor water during the incoming of the tide. The harbor temperature was about 59°F.

System 1. Flame Sprayed Aluminum. This metallized system consisted of a flash coat of flame sprayed steel plus a coat of flame sprayed aluminum. The average thickness was 5 mils (0.005 inch). After two years of exposure the splash and atmospheric zones were assigned a protection rating of 9. Slight spotty pinpoint rusting was in evidence. The tidal zone was receiving very slightly less protection and given a rating of 8+. Most of the rusting appeared at joints and over rounded surfaces where the aluminum coating was thin. It is desirable during metallizing that the flame sprayed molten metal impinge on the prepared surface at a 90 degree angle to give maximum bonding. This procedure is difficult to fulfill over rounded surfaces.

System 2. Flame Sprayed Aluminum, Plus a Wash Primer Sealer. This system was the same as System 1, but in addition had one coat of wash primer (MIL-P-15328B) applied as a seal coat. The average thickness was 6 mils.

The benefit of the wash primer seal coat was demonstrated by the fact that these test piles were receiving excellent protection after two

years. The assigned rating was 10 in the upper zones and 9+ in the tidal zone. As with System 1, rusting appeared at joints and over rounded surfaces.

Systems 3, 4 and 5. Steelmate. This polyester coating was an experimental coating formulated by British Columbia Research of Vancouver, Canada. The average dry film thicknesses were 4 mils, 10 mils, and 6 mils, respectively. After curing, these coatings were easily indented with the thumbnail. These three systems differed only slightly in composition, resulting primarily in a difference in thixotrophy.

After about one year of exposure, these polyester coatings were shrinking, cracking, scaling and peeling in the area from MLW upwards for about one foot. Scaled paint chips pulled from the piling retained a strong odor of solvent. During two years of exposure Systems 3, 4 and 5 had failed in the lower tidal zone. During two years exposure these three systems were giving excellent protection in the splash and atmospheric zones.

System 6. Epoxy-Phenolic. The one coat application of this epoxy-phenolic gave a dry film thickness of 10 mils. This coating cured to a hard, dry film during immersion by the rising tide. This system has given excellent protection during two years of exposure and was given a protection rating of 10 in each exposure zone.

System 7. Coal Tar-Epoxy, C-200, Polyamide Cured. This system applied in one coat gave a dry film thickness of 10 mils and cured to a hard, durable film. After two years the protection of the steel piling by this system was excellent. The assigned protection rating was 10.

System 8. Urethane-Epoxy. This system consisted of two coats; one coat each of a dull brown primer and a white topcoat, to give a hard, dry film of 6.5 mils thickness.

After two years the protection to the atmospheric and splash zones was good and this system received a protection rating of 9. Slight pin-point rusting caused the lowered rating. However, in the tidal zone the protection to the piling was excellent and the system was rated 10. It is entirely possible that if this system had been applied at 9-10 mils thickness as were Systems 6, 7 and 9, the protection in the tidal area would have been better.

System 9. Epoxy (1-B-29), Polyamide Cured. This polyamide cured epoxy was formulated by the Mare Island Naval Shipyard Paint Laboratory for application over damp steel surfaces. It was later made part of an epoxy coating system covered by MIL-P-24441, Epoxy-Polyamide Coating. This epoxy was applied in one coat to give a hard, dry film 8.5 mils thick.

After two years of exposure the protection of the steel piling was excellent in atmospheric, splash and tidal zones, with only an occasional pinpoint rust spot in the upper atmospheric zone (rated 10).

Coatings Applied Using the Cofferdam Concept

Prior to application of these coatings the cofferdam was emplaced and de-watered. The steel piling were sandblasted and the coatings applied to the dry steel surface. The cofferdam was removed immediately, which placed the applied coatings in seawater for curing of the immersed zone and most of the tidal zone. The harbor water temperature was about 59°F.

System 10. Epoxy-Phenolic. At the time this coating was applied to the dry sandblasted steel piling from inside the cofferdam, it was also applied to a removable steel simulated test pile. This test specimen was then suspended in the harbor water for curing and exposure in the atmospheric, splash, tidal and immersed zones.

A one coat spray application of this epoxy-phenolic cured to a hard film with a thickness of 15 mils. Tidal or wave action had no visual effect on the surface of this coating during curing.

After one year of exposure this coating was giving excellent protection to the steel piling and simulated pile in the immersed and tidal zones. The protection was rated 10.

System 11. Coal Tar-Epoxy, C-200, Polyamide Cured. One coat, brush applied, cured to a hard film having a thickness of 17 mils. Tidal or wave action did not damage the surface of the coating during curing.

The piling was receiving excellent protection from this coating one year after application. The protection rating was 10.

System 12. Epoxy, Amine Adduct Cured. This system consisted of one coat of primer and one coat of topcoat. This system was spray applied to the sheet piling and brush applied to the simulated pile. One side of the simulated pile was coated with primer and topcoat and the other side with primer only. The cured film thicknesses were 12 mils on the sheet pile, 22 mils on one side of the simulated pile, and 14 mils for the primer on the opposite side of this pile.

After one year the coating on the sheet piling was in excellent condition and the protection to the piling was rated 10.

The simulated pile was receiving excellent protection on both sides after one year of exposure, although there was slight checking of the white topcoat on the lower half of the simulated pile.

System 13. Coal Tar-Epoxy, C-200, Polyamide Cured. This system was the same as System 11, except that System 13 was spray applied. The

cured film had a thickness of 17 mils. At the time this coating was applied to the dry sandblasted steel piling from inside the cofferdam, it was also applied to a removable steel simulated test pile. This test specimen was then suspended in the harbor water for curing and exposure in the atmospheric, splash, tidal and immersed zones. No damage from tidal or wave action during curing was found.

The protection given to the steel and simulated pile by this system was excellent and was given a protection rating of 10 after one year of exposure.

System 14. Urethane-Epoxy. At the time this coating was applied to the dry sandblasted steel piling from inside the cofferdam, it was also applied to a removable steel simulated test pile. This test specimen was then suspended in the harbor water for curing and exposure in the atmospheric, splash, tidal and immersed zones.

This system consisted of one coat of brush applied primer and one coat of brush applied topcoat. The system cured to a hard film having a total thickness of 10 mils. Tidal or wave action did not damage this coating system during curing.

After one year of exposure the simulated removable pile and the steel sheet piling were receiving excellent protection and were rated 10.

System 15. Epoxy, Polyamide Cured. This epoxy system consisted of one brush applied primer coat and one brush applied topcoat. The system cured to a rather soft film having a total thickness of 30 mils. During curing no damage was observed from tidal or wave action.

Although protection to the steel piling was excellent with no rusting in evidence, the topcoat was shrinking giving an appearance of cracking. Even after one year exposure, this coating was still slightly soft. Barnacles were cutting into the coating, but after one year they had not penetrated the coating to the bare steel.

Coatings Applied Underwater to Sandblasted Steel

Thicknesses of Systems 17, 18, 19 and 20 were measured on the removable test piles. During application and curing the harbor water temperature was about 59°F.

System 16. Steelmate (Antifouling). This polyester coating was easily applied by a representative of the supplier by brushing at a very low tide period, the application extending from about one foot above to one foot below MLW. This coating did not cure to a hard film. The cured film thickness was not measured because at subsequent inspections the coating was below MLW.

After about one year this coating had scaled due to shrinking and cracking and lost bond to the steel piling; after two years it had failed and was rated 7. As was found with steelmate applied above MLW, the paint chips that were peeled from the piling had a strong solvent odor.

System 17. Polyester-Flake Glass. This coating was applied underwater by brush to sandblasted steel sheet and simulated pile. The application was done by Seabee personnel with no previous experience at applying coatings underwater. Attempts by them to apply this coating by roller underwater were unsuccessful as the roller tended to push the coating away from the steel substrate rather than spread it out. They much preferred the brush method of application. From both laboratory and field observations, the polyester systems (Systems 16 and 17) were much easier to apply underwater than other formulations tested. It should be noted that the other formulations were also much more viscous and consequently had greater film thickness. The total cured thickness of the System 17 coating was about 12 mils on the sheet piling and 8 mils on the simulated pile.

After one year of exposure, there was light pinpoint rust in a few areas on the sheet pile and the protection to the piling was considered very good. The assigned rating was 9+.

The simulated pile had slightly less coating thickness than did the sheet piling. This coating, after one year, had moderate pinpoint rusting in the upper half of the pile and moderate blistering and rusting in the lower half. The coating of the upper one-third of the piling had wrinkled but the lower two-thirds was smooth. The overall protection after one year was good and was rated 8.

System 18. Aluminum-Coal Tar-Epoxy. The application of System 18 was accomplished satisfactorily by Seabee divers by brushing, although not so easily as with the polyester coatings. Displacement of water from and preferential wetting of the sandblasted steel by the aluminum-coal tar-epoxy was relatively slow. The total applied thickness was 17 mils on the sheet piling and 10 mils on the simulated pile. There was no rusting, blistering, or loss of bond after one year of exposure. The rating was 10.

System 19. Epoxy. System 19 was brush applied to the piling comparatively easily above water where it was tied into the coating applied above MLW, but the Seabee divers found the material easier to apply by glove underwater because of its high viscosity. The total thickness of this system was 18 mils and over on the sheet piling and about 20 mils on the simulated pile.

After one year of exposure, slight blistering and checking of the coating and rusting of the steel piling were observed. The piling received relatively good protection, however, and the coating was given a rating of 9.

The condition of the coating on the simulated pile was quite similar to that on the sheet piling section. In addition there was some wrinkling of the coating, probably due to the movement of the pile in the water during relocation of the panel while the coating was still soft.

System 20. Epoxy. Application was initiated by Seabee personnel by use of a brush in the area that extended above water, but hand application was necessary below water. This coating was even more viscous than System 19 and consequently more difficult to apply. The cured film thickness of this coating was 25 mils on the sheet piling and 45 mils on the simulated pile.

After one year the protection to the steel piling was excellent and was rated 10.

The coating over the lower two-thirds of the simulated pile was giving excellent protection with no rusting or blistering. However, during cure, this coating had drawn toward the center of the simulated pile in the atmospheric zone, leaving the edges relatively unprotected. As a result, the pile was receiving poor protection in this area and was given a protection rating of 7.

Coatings Applied Underwater to Von Arx Gun Cleaned Steel

System 21. Epoxy. System 21, applied over a Von Arx gun underwater cleaned surface, was an experimental two-component epoxy system formulated for extremely rapid cure underwater. It was difficult to apply at a water temperature of 59°F without pinholes. This coating was also slightly damaged during installation at the exposure site while it was still soft. Application of a polyester-flake glass and an aluminum-coal tar epoxy (Systems 17 and 18, respectively) were made over both sandblasted and Von Arx gun underwater cleaned simulated steel piles. This was done in order to compare cleaning rates and application ease on the simulated steel piles. The cleaning rate underwater with the Von Arx gun was comparable to that of sandblasting, and the resultant surface appeared to be as satisfactory as a blast cleaned surface for coating underwater. No difference was experienced in underwater application rates over either type of cleaned surface.

DISCUSSION

All the coatings of Group A were applied at periods of low tide, and except for the metallized coating, cured during wetting by the incoming tide.

The flame sprayed aluminum coating, System 2, with the wash primer seal coat is performing considerably better than the unsealed aluminum, System 1. The few areas of light rust in System 2 are on rounded surfaces and at joints between the piles. In these areas the aluminum coating is slightly less than the required thickness.

The polyester coatings of British Columbia Research did not cure properly because of entrapped solvent in the tidal area. In the atmospheric and splash zone the coating appears to be properly cured but is not very hard or scuff resistant; however, it has given excellent protection to the steel piling for two years.

The epoxy-phenolic, System 6, and the coal tar-epoxy, System 7, have given excellent protection for two years with no signs of deterioration. The epoxy-phenolic, when applied to simulated piling before driving, have demonstrated exceptional performance in previous tests.[3]

The urethane-epoxy, System 8, and the epoxy, System 9, were both developed for application over damp steel surfaces. System 9 appeared slightly superior to System 8; however, both coatings gave satisfactory protection to the piling for two years. The System 8 topcoat had a slight tendency to crack.

Regarding these eight coating systems, the unsealed aluminum, System 1, and polyester coatings, Systems 3, 4 and 5, were showing initial signs of deterioration in the tidal area. The remaining coatings, epoxy-phenolic, System 6; coal tar-epoxy, System 7; urethane-epoxy, System 8; and epoxy, System 9, all gave good protection under the conditions of application, curing and exposure.

All the coatings of Group B were applied using the cofferdam concept and immediately after application were subjected to tidal action upon removal of the cofferdam. Thus, all except the upper approximate one-fourth of the coated area cured underwater.

Five coatings were applied and exposed in this manner. Except for System 15, epoxy, these systems all cured under these conditions to hard durable films. System 15 cured to a rather soft film of 30 mils thickness; the topcoat had a tendency to crack and barnacles damaged the coating. However, the remaining coatings (System 10, epoxy-phenolic; Systems 11 and 12, coal tar-epoxy; System 12, epoxy; and System 14, urethane-epoxy) have given excellent protection to the piling from 2 feet below MLW upwards to MHW (mean high water) for a period of one year. Again, System 10 was found to be a satisfactory coating for application to simulated piling before driving.[3]

The coatings of Group C were applied underwater from slightly above MLW to about 1 foot below MLW.

Again the System 16, Steelmate, antifouling, failed to cure properly and failed in about one year because of solvent entrapment. Cracking, scaling and peeling occurred during failure of this coating. Thus, its antifouling properties could not be determined.

The polyester-flake glass, System 17, was the easiest to apply underwater, but during underwater exposure had a tendency toward pinpoint rusting. This rusting lowered its protection rating.

Application of the aluminum-coal tar-epoxy, System 18, was slow but very satisfactory. This system gave the best protection to the immersed steel piling during the one-year exposure period of all coatings applied underwater.

The two epoxy Systems 19 and 20 were difficult to apply by brush because of their higher viscosities. Hand or glove application was necessary with subsequent smoothing out by brushing. System 19 provided relatively good protection from corrosion despite some checking of the coating and pinpoint rusting. The epoxy, System 20, did give good to

excellent protection to the steel substrate during one year of immersed exposure, but because of difficulty in application, the thickness of this coating was 25 to 45 mils. The coating had a tendency to draw away from edges during cure.

Cleaning of steel, using a Von Arx gun, was comparable to sandblast cleaning, both in terms of cleaning rate and providing a suitable surface for coating underwater. A larger gun with more fine needles could probably greatly increase the cleaning rate. Such a method of cleaning would also have the advantages of simpler equipment and skills required by the diver.

CONCLUSIONS

1. The following coating systems applied at a thickness of 10 mils will cure satisfactorily and give excellent protection for over two years to steel piling when applied to sandblasted surfaces from slightly above MLW upwards to the top of the piling.

   a. Flame sprayed aluminum with a wash primer seal coat (System 2)

   b. An epoxy-phenolic (System 6)

   c. Coal tar-epoxy, C-200 (System 7)

   d. An epoxy-urethane (System 8)

   e. An epoxy 1-B-29 (System 9)

2. A seal coat (e.g. wash primer) over flame sprayed aluminum is desirable to reduce the incidence of pinhole rusting.

3. The following coatings at 10 mils dry film thickness will cure satisfactorily and give excellent protection for over one year when applied to steel sheet piling using the cofferdam concept.

   a. An epoxy-phenolic (System 10)

   b. An epoxy (System 12)

   c. A coal tar-epoxy, C-200 (System 13)

   d. An epoxy-urethane (System 14)

4. An aluminum-coal tar-epoxy (System 18) can be satisfactorily applied underwater to sandblasted steel, will cure to a hard, durable, well-bonded coating, and when applied to sandblasted steel piling at 15 mils cured film thickness will give excellent protection for over two years.

Table 2. Coating Performance

System Number	Years Exposed	Areas			Remarks
		Atmos. and Splash*	Tidal*	Immersed*	
1	2	9	8+	—	Spotty Pinpoint rusting - splash zone. Rusting at joints - tidal zone.
2	2	10	9	—	Very slight rusting in joints.
3	2	10	7	—	Failure due to shrinking, cracking, scaling, promoted by solvent entrapment.
4	2	10	7	—	See above.
5	2	10	7	—	See above.
6	2	10	10	—	
7	2	10	10	—	
8	2	9	10	—	Slight pinpoint rusting - splash zone. Coating thickness, 6.5 mils, believed insufficient.
9	2	10	10	—	
10	1	—	10	10	
11	1	—	10	10	
12	1	—	10	10	
13	1	—	10	10	
14	1	—	10	10	

Table 2. (Cont'd)

System Number	Years Exposed	Areas: Atmos. and Splash*	Areas: Tidal*	Areas: Immersed*	Remarks
15	1	—	10	10	Coating remained scft, had barnacle damage; no rusting present.
16	2	—	--	7	Shrinking, scaling and peeling caused failure; some solvent entrapment.
17	1	(8**)	(8**)	9+	Slight pinpoint rusting - immersed, pinpoint rusting - atmos. zone, blistering - tidal zone.
18	1	(10**)	(10**)	10	
19	1	(9**)	(9**)	9	Slight wrinkling of coating on simulated pile.
20	1	(7**)	(10**)	10	Coating pulled away from edges in atmos. zone, and rusting occurred.

* 10 - Excellent protection, no rusting or coating damage.
9 - Good protection, no damage or rusting over 90% of coating surface.
8 - Fair protection, no damage or rusting over 70% of coating surface.
7 - Failed, rusting and coating damage over 30% of coating surface.

**Ratings of coatings applied to simulated piles.

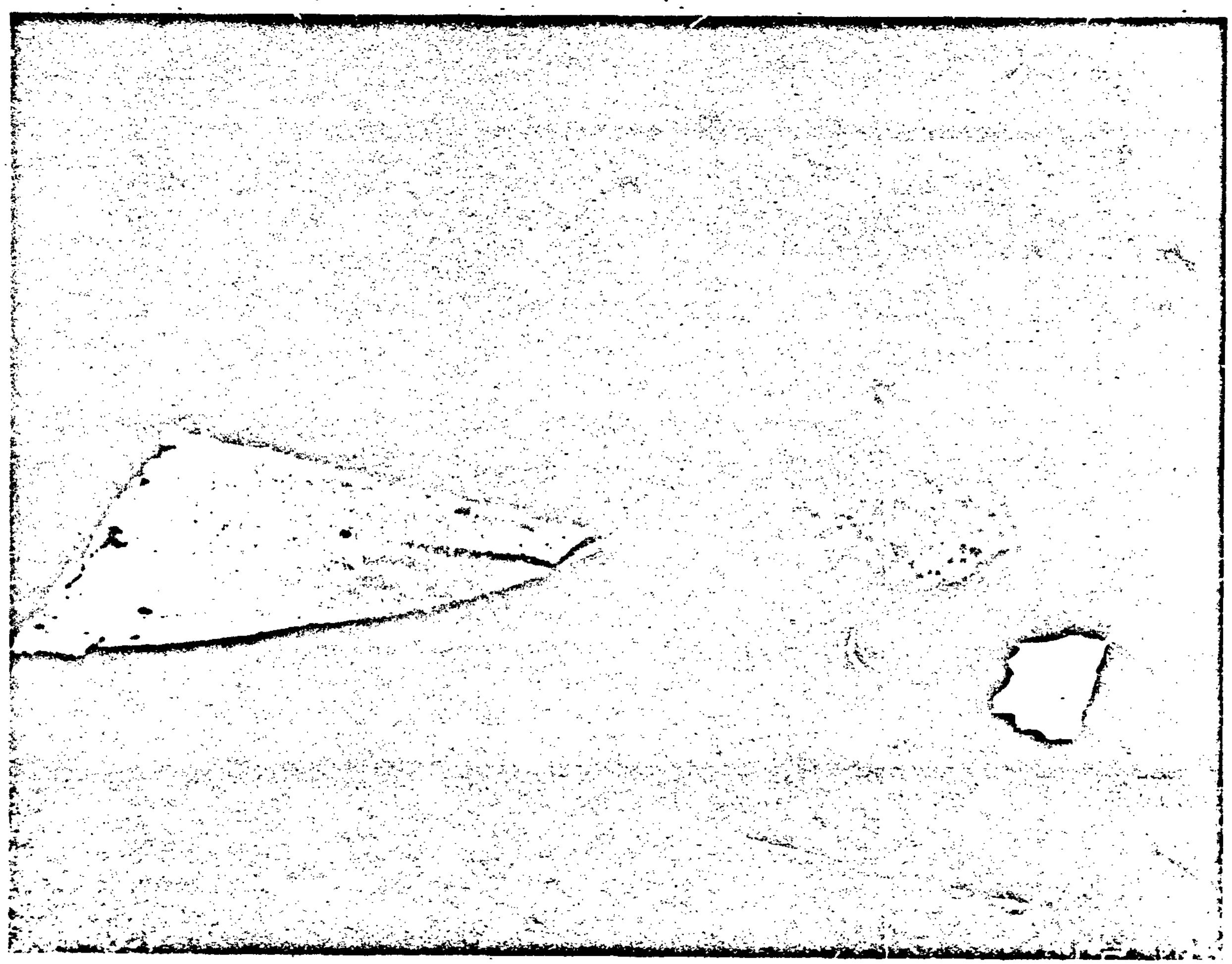

Figure 1. Peeling of paint applied underwater to steel panel.

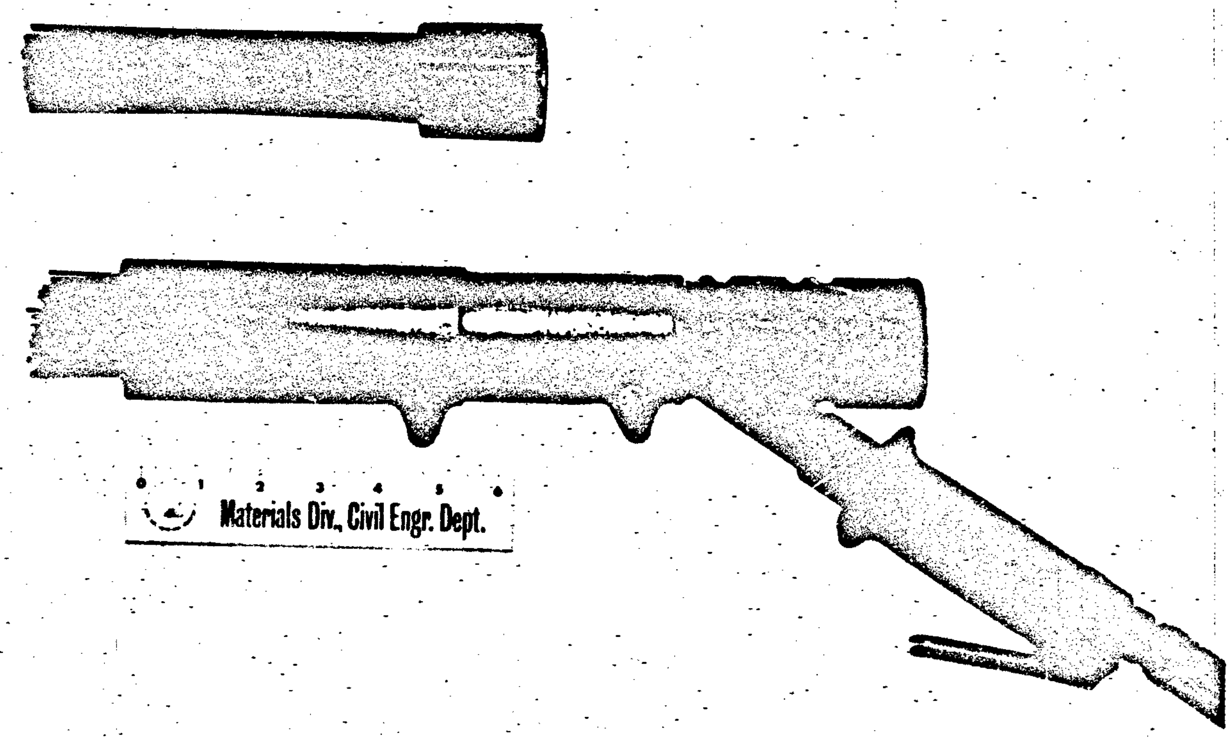

Figure 2. Von Arx Model 3B needle gun for removing rust and scale.

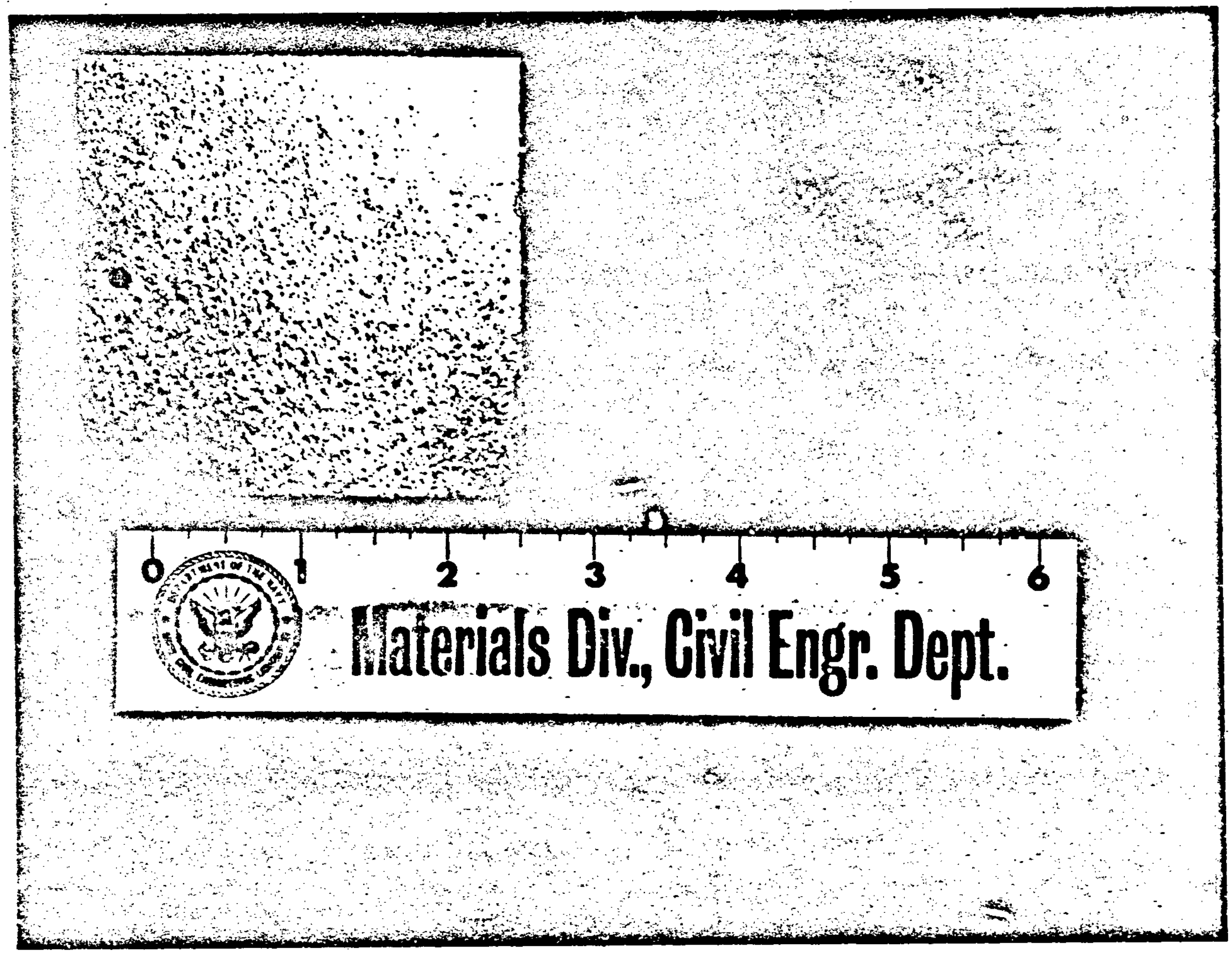

Figure 3. Rusted steel panel on right and similar steel panel on left after cleaning with Von Arx gun.

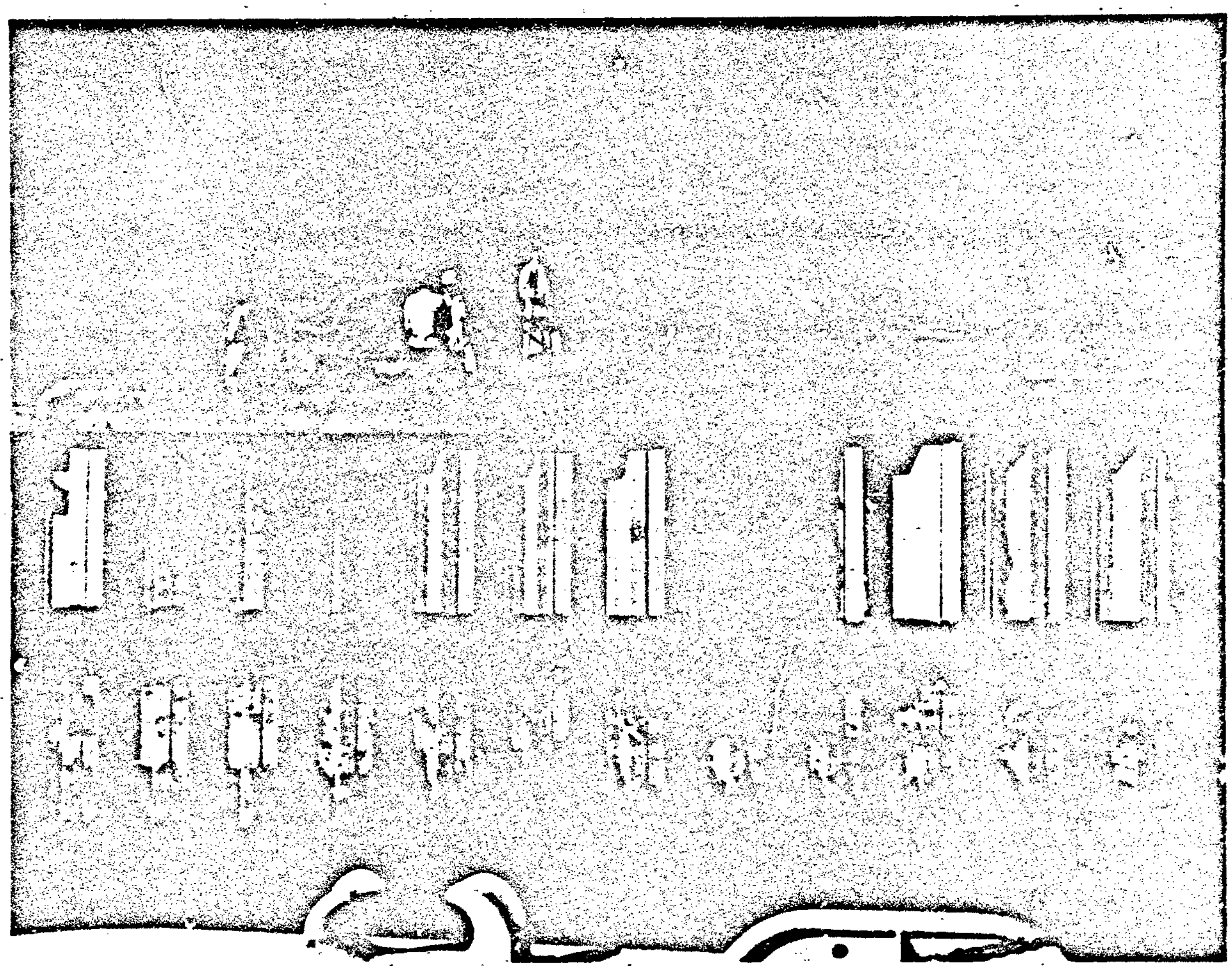

Figure 4. Repetitive pattern created by the interlocked Z-shaped piles.

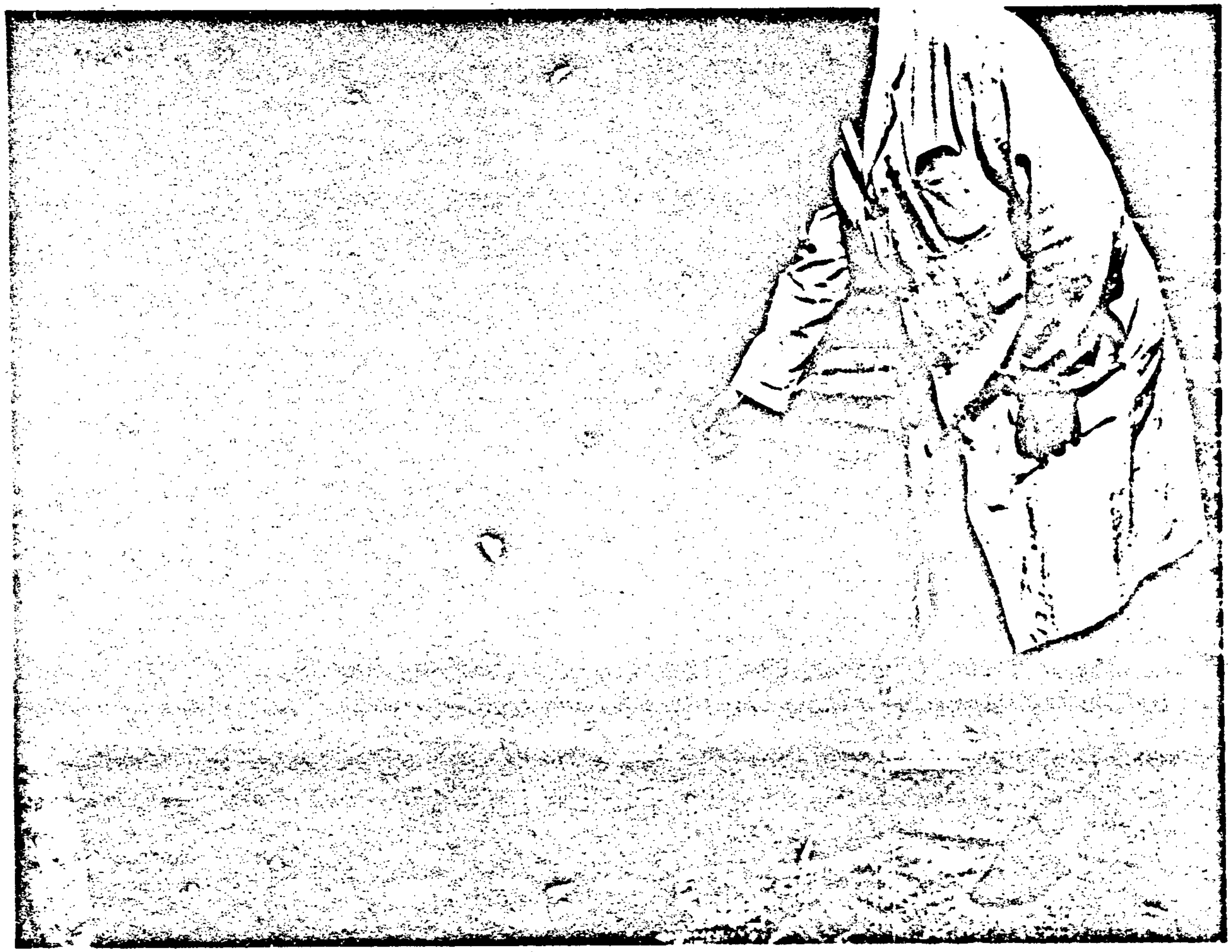

Figure 5. Inflatable-compressable rubber tube for sealing floor of cofferdam against piling.

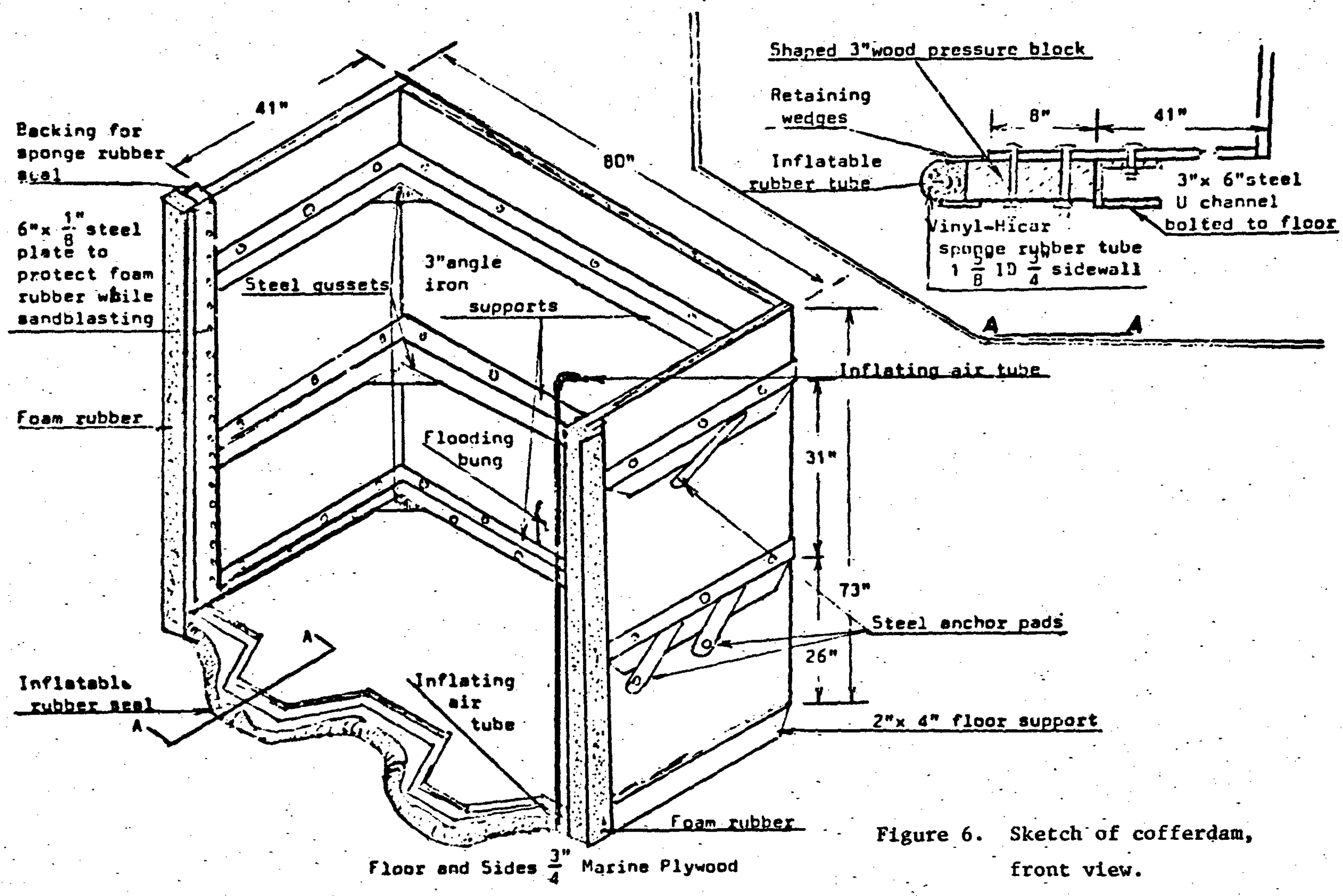

Figure 6. Sketch of cofferdam, front view.

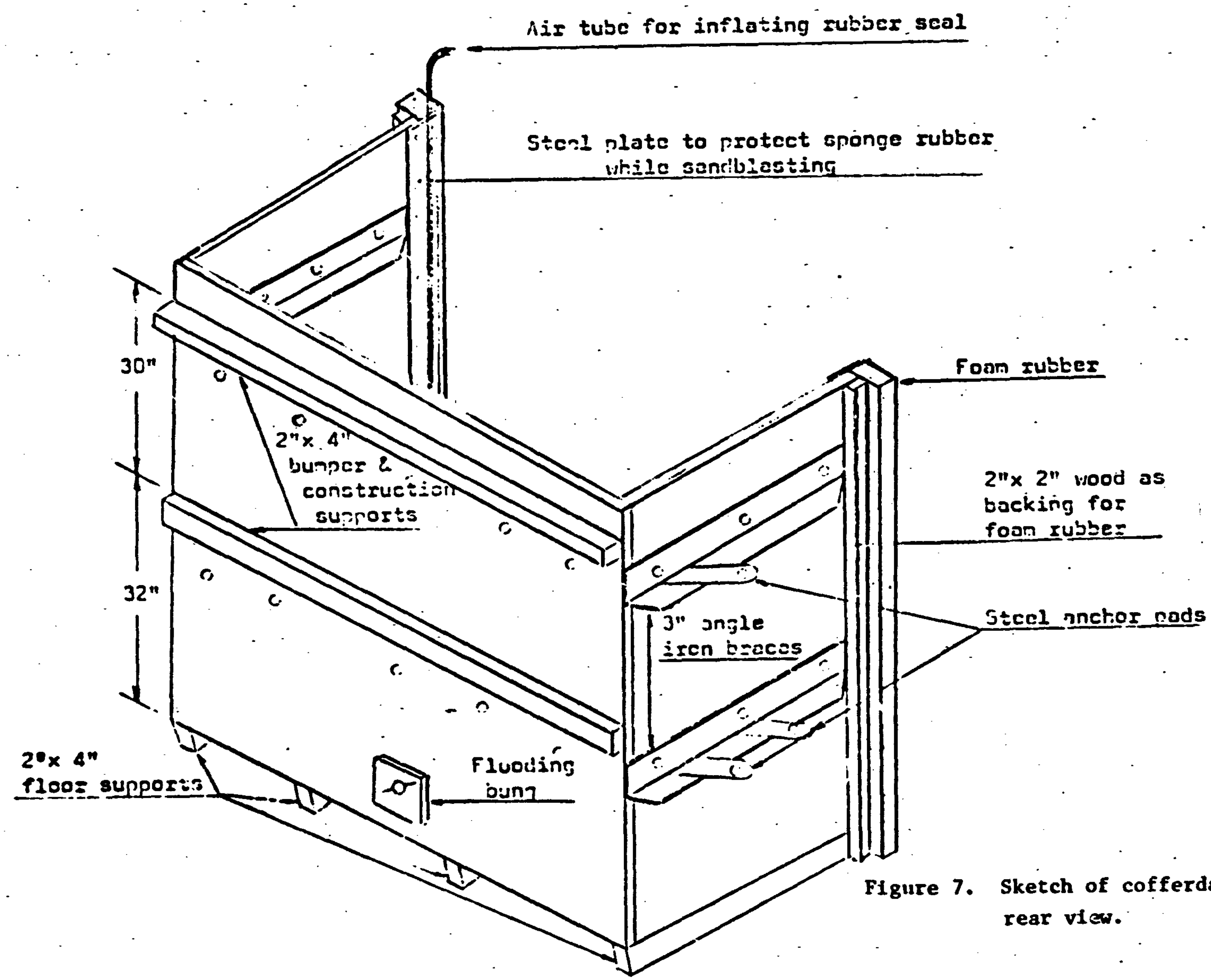

Figure 7. Sketch of cofferdam, rear view.

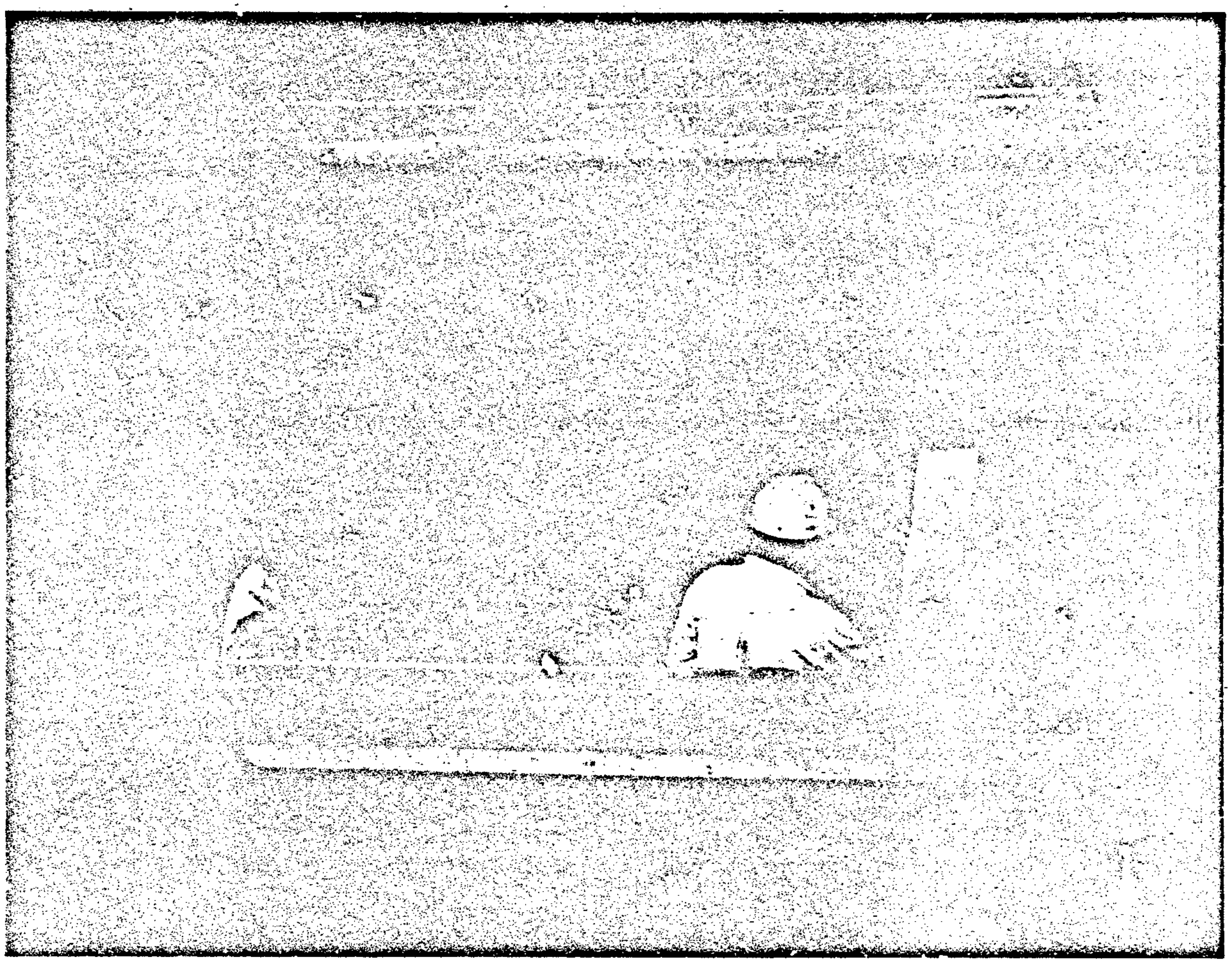

Figure 8. Painting 2 feet below to 5 feet above MLW from inside the cofferdam.

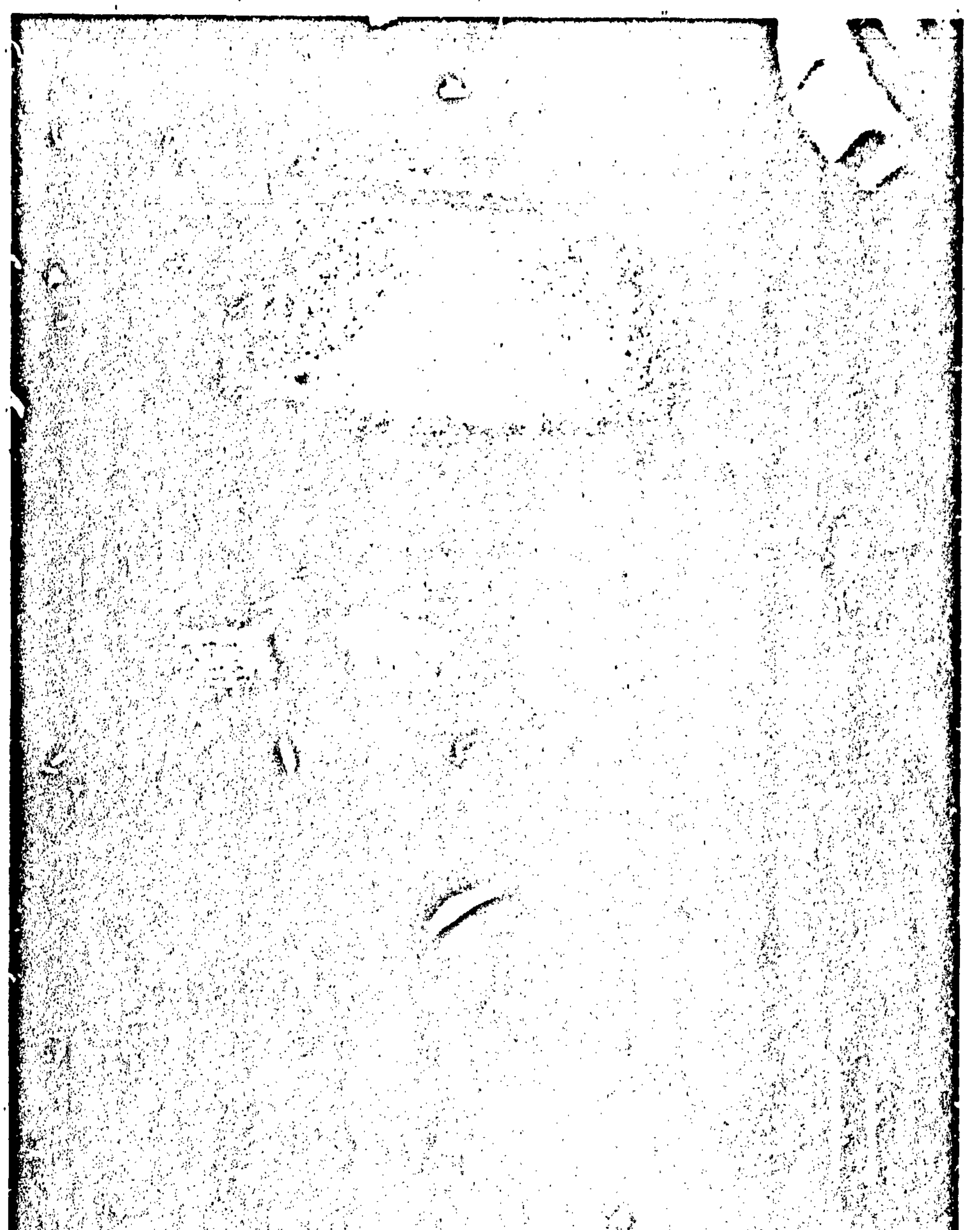

Figure 9. Underwater painting with a pressure feed brush.

Appendix A

BRUSHABLE COATINGS TESTED IN LABORATORY

Brolite Corrosion Inhibiting Underwater Primer (Andrew Brown Company)

Bolite T-1053 Flexible A-711 Damp Surface Epoxy Polyamide Coating (Andrew Brown Company)

Amercoat 83 (Ameron)

Amercoat 83 Fast Cure (Ameron)

Amercoat 84 (Ameron)

Ameron No. 2040 White (Ameron)

Carbomastic X-2256-138 (Carboline Company)

Carboglos X-1600-68 (Carboline Company)

Various Steelmate formulations (B.C. Research)

Formulations with Sur-Wet RII Curing Agent (Pacific Vegetable Oil Corporation) and various epoxy resins

Zinc-Lock 530 Underwater-Curing Epoxy (Zinc-Lock Company)

Sta-Crete R-67X (Sta-Crete, Incorporated)

Sta-Crete R-67W (Sta-Crete, Incorporated)

Plasite 9009 (Wisconsin Protective Coating Corporation)

Cono/Glaze White (Con/Chem Incorporated)

Sika Underwater Kote DP9024 (Sika Chemical Corporation)

Proline Underwater Antifouling Paint (Proline Paints)

Aquacoat 2830 (Citrex Corporation)

Epomarine 3534 (H. V. Hardman Company)

Gaco E-5311 (Gaco Western Incorporated)

Mare Island Epoxy-Polyamide 1-B-29 (U.S. Navy Paint Laboratory)

Numerous experimental formulations prepared by NCEL

Appendix B

COATING SYSTEMS TESTED IN THE FIELD

A. Above Mean Low Water (for further description, see Reference 9)

System 1. Flame Sprayed Aluminum

Spraysteel (1/8 inch diameter steel wire)	0.5 mils or less
Aluminum Wire - MIL-M-3800	5 mils avg.
Total	5 mils avg.

System 2. Flame Sprayed Aluminum plus Sealer

Spraysteel (1/8 inch diameter steel wire)	0.5 mils or less
Aluminum (1/8 inch diameter aluminum wire)	5 mils avg.
Wash Primer (MIL-P-15328B, 1 coat)	0.5 mils max.
Total	6 mils avg.

System 3. Steelmate

Steelmate (1 coat)	4 mils avg.

System 4. Steelmate

Steelmate (2 coats)	10 mils avg.

System 5. Steelmate

Steelmate (1 coat)	6 mils avg.

System 6. Epoxy-Phenolic

Epoxy-Phenolic (1 coat)	10 mils avg.

System 7. Coal Tar-Epoxy C-200

Coal Tar-Epoxy (1 coat)	10 mils avg.

System 8. Urethane-Epoxy

Primer (1 coat for damp application)	3 mils avg.
Topcoat (1 coat)	3.5 mils avg.
Total	6.5 mils avg.

System 9. Epoxy (1-B-29)

Primer (1 coat for damp application)		3 mils avg.
Topcoat (1 coat)		3.5 mils avg.
	Total	6.5 mils avg.

B. Applied Using the Cofferdam

System 10. Epoxy-Phenolic

Epoxy-Phenolic (1 coat) Spray	15 mils avg.

System 11. Coal Tar-Epoxy C-200, Polyamide Cured

Coal Tar-Epoxy (1 coat) Brush	17 mils avg.

System 12. Epoxy, Amine Adduct Cured

Epoxy (1 coat) Spray	12 mils avg.

System 13. Coal Tar-Epoxy, C-200, Polyamide Cured

Coal Tar-Epoxy (1 coat) Spray	17 mils avg.

System 14. Urethane-Epoxy

Primer (1 coat) Brush		5 mils avg.
Topcoat (1 coat) Brush		5 mils avg.
	Total	10 mils avg.

System 15. Epoxy, Polyamide Cured

Primer (1 coat) Brush		20 mils avg.
Topcoat (1 coat) Brush		10 mils avg.
	Total	30 mils avg.

C. Coatings Applied Underwater

(Thickness on Systems 17, 18, 19 and 20 measured on removable test piles)

<u>System 16. Steelmate, Antifouling</u>	
Steelmate (1 coat)	Thickness not measured
<u>System 17. Polyester-Flake Glass</u>	
Polyester-Flake Glass (1 coat)	12 mils avg.
<u>System 18. Aluminum-Coal Tar-Epoxy</u>	
Aluminum-Coal Tar-Epoxy (1 coat)	17 mils avg.
<u>System 19. Epoxy</u>	
Epoxy Primer (1 coat)	18 mils avg.
<u>System 20. Epoxy</u>	
Epoxy (1 coat)	25 mils avg.
<u>System 21. Epoxy</u>	
Epoxy (1 coat)	30 mils avg.

Appendix C

COATINGS SOURCES

System No., Source

1. Spray Steel and Aluminum Wire

   Metco Incorporated
   518 No. Western Avenue
   Los Angeles, California 90029

2. Spray Steel and Aluminum Wire

   Metco Incorporated
   518 No. Western Avenue
   Los Angeles, California 90029

   Wash Primer

   Pro Line Company
   2646 Main Street
   San Diego, California 92113

3. Steelmate Products

   British Columbia Research
   3650 Wesbrook Crescent
   Vancouver 167, Canada

4. Steelmate Products

   British Columbia Research
   3650 Wesbrook Crescent
   Vancouver 167, Canada

5. Steelmate Products

   British Columbia Research
   3659 Wesbrook Crescent
   Vancouver 167, Canada

6. Phenoline 300 Orange

   Carboline Company
   328 Hanley Industrial Court
   St. Louis, Missouri 63144

7. Tarset-C-200

Porter Coatings Division
400 South Thirteenth Street
Louisville, Kentucky 40201

8. Urethane-Epoxy Primer and Topcoat

Pro Line Company
2646 Main Street
San Diego, California 92113

9. Epoxy-Polyamide I-B-29

San Francisco Bay Naval Shipyard
Mare Island Paint Laboratory
Vallejo, California 94542

10. Phenoline 300 Orange

Carboline Company
328 Hanley Industrial Court
St. Louis, Missouri 63144

11. Tarset C-200

Porter Coatings Division
400 South Thirteenth Street
Louisville, Kentucky 40201

12. Epomarine 3534

H. V. Hardman Company, Inc.
Belleville, New Jersey 07109

13. Tarset C-200

Porter Coatings Division
400 South Thirteenth Street
Louisville, Kentucky 40201

14. Urethane-Baker Castor Oil Formulation

Pro Line Company
2646 Main Street
San Diego, California 92113

15. Sika Epoxy

    Sika Chemical Corporation
    P.O. Box 899
    Passaic, New Jersey 07056

16. Steelmate Products - Antifouling

    British Columbia Research
    3650 Wesbrook Crescent
    Vancouver 167, Canada

17. Carboglas X-1600-68

    Carboline Company
    328 Hanley Industrial Court
    St. Louis, Missouri 63144

18. Carbomastic X-2256-138

    Carboline Company
    328 Hanley Industrial Court
    St. Louis, Missouri 63144

19. Sika - Epoxy

    Sika Chemical Corporation
    P.O. Box 899
    Passaic, New Jersey 07056

20. Sta-Crete Epoxy

    Sta-Crete Incorporated
    893 Folsom Street
    San Francisco, California 94107

21. Ameron No. 2040 White

    Ameron
    201 No. Berry Street
    Brea, California 92621

REFERENCES

1. Naval Civil Engineering Laboratory. Technical Report R-397: Protective coatings for steel piling: Correlation of results of parallel test exposures at Port Hueneme and Guam, by C. V. Brouillette and R. L. Alumbaugh, August 1965.

2. __________. Technical Report R-490: Protective coatings for steel piling: Results of harbor exposures on ten-foot simulated piling, by R. L. Alumbaugh and C. V. Brouillette, November 1966.

3. __________. Technical Report R-711: Protective coatings for steel piling: Additional data on harbor exposure of ten-foot simulated piling, by R. L. Alumbaugh and A. F. Curry, February 1971.

4. __________. Technical Report R-300: Underwater-curing epoxy coatings, by R. W. Drisko, J. W. Cobb and R. L. Alumbaugh, 8 May 1964.

5. __________. Technical Report R-390: Bonding of underwater-curing epoxies, by R. W. Drisko, June 1965.

6. __________. Technical Report R-552: Application of underwater-curing epoxies to steel sheet piling at USNSB New London, by R. W. Drisko, April 1967.

7. H. Pande. "Coatings Applied Underwater," National Association of Corrosion Engineers, Northeast Regional Conference, New York, 22 October 1968.

8. Mare Island Paint Laboratory. Report 66-1: Coatings for application to cold, damp and difficult-to-clean ship surfaces, by E. G. Branstetter, Vallejo, California, July 1966.

9. Naval Civil Engineering Laboratory. Technical Note N-1068: In-place application of protective coatings to sheet steel piling, by C. V. Brouillette and R. W. Drisko, December 1969.

10. __________. Technical Report R-097: Corrosion survey of steel sheet piling, by C. V. Brouillette and A. E. Hanna, December 1960.

11. __________. Technical Report R-467: Second corrosion survey of steel sheet piling, by C. V. Brouillette and A. E. Hanna, August 1966.

12. __________. Letter Report: Cofferdam concept for in-place painting of steel piling below mean low water, by C. V. Brouillette, 24 September 1970.

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13. ABSTRACT

Several materials and application procedures have been investigated for use in the in-place maintenance painting of steel piling. Coatings designed for application to dry sandblasted piling above the waterline have performed well for two years. Coatings designed for application between tides, so that they are wetted with seawater almost immediately after application, or for application underwater, have performed well for one year.

Application above water was accomplished by conventional spraying. Part of the application between tides and a few feet below mean low water was accomplished by a special cofferdam designed for use on steel sheet piling. The rest was accomplished by brushing coatings specially formulated for underwater application. Surface preparation for the latter application was generally by underwater sandblasting, but cleaning with a pneumatic needle gun was also investigated. Laboratory testing indicated that needle gun cleaning was a promising technique. It was also used to screen candidate underwater-applied coatings.

(Cont'd)

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Underwater-applied coatings						

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(PAGE 2)

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While the performances of some test coatings are quite promising to date, their further exposure and investigation of new materials and application procedures will continue in order to make them more practical and economical.

SUPPLEMENTARY

INFORMATION

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From: Commanding Officer
To: Distribution List

Subj: Errata Sheet for Technical Note N-1222, "In-Place Maintenance Painting of Steel Piling," by C. V. Brouillette and R. W. Drisko

1. Please make the following pen and ink corrections on the pages listed.

Page 13, under the heading Conclusions, point 1, please delete the words "applied at a thickness of 10 mils"

Page 13, under the heading Conclusions, point 3, please delete the words "at 10 mils dry film thickness"

Page 13, under the heading Conclusions, point 4, lines 3 and 4, respectively, please change 15 mils to "17 mils" and two years to "one year."

Page 27, under System 9. Epoxy (1-B-29), delete "Primer (1 coat for damp application) 3 mils avg." and change Topcoat to "Epoxy" and 3.5 mils avg. to "8.5 mils avg.". The total then becomes 8.5 mils avg.

W. S. Haynes

W. S. HAYNES
By direction